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The chronophotographer Ernst Kohlrausch and the physics of gymnastics

Chronophotography, the technique for recording images of rapidly occurring movements in a series of separate shots, was developed in the last quarter of the nineteenth century. After more than 100 years, research has explored the subject at some length. The physiologists and doctors involved from the start saw these series photographs as an aid towards a better understanding of the progressions of movements. They focused their attention on the analytical aspect of this imaging technique that dissected the temporal process. The history of film, on the other hand, has usually described the synthesis of the separate shots, repeatedly produced by different kinds of replay and projecting equipment recovering the 'living' images from the 'still' ones, as an important stage in the development of cinematography. To what extent the interplay of 'visualisation and visibility' peculiar to chronophotography was also capable of firing the imagination can be traced in the variety of ways this imaging technique is reflected in the fine arts. It is not surprising that, in the wake of the leading research paradigm of the 'pictorial turn', chronophotography proves to be a multifaceted model applied increasingly often to the complex visualisation strategies in science, art and technology.[1]

Our knowledge of chronophotography is associated mainly with the names of the Anglo-American Eadweard Muybridge[2] and the Frenchman Etienne-Jules Marey.[3] For both of them chronophotography turned out to be the crystallisation point of their work. Its success is reflected not least in the financial support granted to their undertakings and the resultant recognition by society. Monographs on Ottomar Anschütz,[4] Georges Demeny[5] and Albert Londe[6] have only recently considerably enlarged the repertory on this photographic technique and its wide variety of possible uses.

The attempt to rank Ernst Kohlrausch among this illustrious circle of the pioneers of chronophotography is based on very spare testimony.[7] Since 1933 the Deutsches Museum has preserved four of Kohlrausch's pieces of equipment. Two of them used to be exhibited in the former permanent display on photography and film. The recent rediscovery of 18 sets of sequential photographs in the museum's archives, completing the two sets that have been known for some time, provides an opportunity to reassess, on a broader basis of original source material, the intentions and activities of this researcher interested in the instantaneous photography of school gymnastics.

Measurement and representation

In comparison with the great well-known experts in chronophotography, the life story of Ernst Kohlrausch (1850–1923) offers few highlights. Like his father and grandfather, he chose the teaching profession, which he took up in 1875 as the youngest teacher at the newly founded Kaiser Wilhelm Gymnasium (high school) in Hanover. He continued to teach until his retirement in 1916. Kohlrausch had always been keen on physical education at school and university, and he passed an additional state examination as a PE teacher in 1874. Thus he was able to combine the subjects he taught, physics and mathematics, with his passion for physical exercise, which he practised actively in the many associations of which he was a member.[8]

At the fourth meeting of the Nordwestdeutscher Turnlehrer-Verein in Brunswick in 1880, Kohlrausch had his first opportunity to speak to a larger audience about his combined interest in physics and gymnastics. 'Doing gymnastic exercises is moving, and each movement obeys the laws of physics,' he said. His remarks on the laws of gravity and their interplay with the muscular power of the gymnast were intended as directions for apparatus work, so that a PE teacher could 'give the correct instructions and be able to assess the difficulty of an exercise'.[9] In his lecture Kohlrausch tried to clarify points, such as the constant displacement of the centre of gravity and the effects of the lever law and the law of inertia, with the help of a wooden doll with movable limbs, a rod and a ball on a string. When the lecture was published later without illustrations, readers were left to rely on their imagination alone.

However, the mechanical understanding of the human body that Kohlrausch presented was not as utterly new as he claimed. The first attempts to extend the knowledge of the human body beyond anatomy to the entirety of the human being's vital functions and to explain them with the help of geometry and mechanics go back to the seventeenth century. In his book *De motu animalium*, the Neapolitan doctor Giovanni Alfonso Borelli described the external and internal movements of both the animal and the human organism with a view to the possible measurement and calculation of their dynamics.[10] On the subject of muscular activity during locomotion, Borelli concentrated particularly on the *centrum gravitatis*.[11] Large numbers of engravings were intended to make his observations as clear as possible, yet they are little more than schematic representations of the mechanics described, with letters and lines indicating the field of force of the *machina humani corporis*.[12]

After the eighteenth century, during which the idealistic idea of kinetic energy as vital power had been preferred, the mechanistic paradigm of the body was revived at the beginning of the nineteenth. With new instruments making it possible to measure and record bodily functions, the situation was fundamentally changed. Observational criteria were now available to record and quantify research results.[13] Measuring equipment, such as the spirometer (1846) by John Hutchinson for examining lung function, or the sphygmometer (1835) by Julius Hérisson, which recorded the pulse beat on a mercury column, first made the processes hitherto concealed inside the body visible to all.[14] The kymographion (1847) by the physiologist Carl Ludwig, as well as Karl Vierordt's sphygmograph (1854), recorded pulse rates directly onto a chart and thus provided the continuous registration of a transient process in relation to its duration.[15]

Registering the movements of the whole human body, however, continued to be difficult. A first attempt at representing the human gait based on measured data was undertaken by the brothers Wilhelm and Ernst Heinrich Weber in 1836 in their study, *Mechanik der menschlichen Gehwerkzeuge*. It sparked an active preoccupation with human locomotion and was long considered exemplary in the field of physiology.[16] In 1872 Gaston Carlet carried out experiments in recording human locomotion graphically in Marey's laboratory. Besides measuring the number, length and frequency of steps, he focused particularly on recording the intensity and duration of the pressure when the feet touched the ground.[17] A combined research method using a 'footprint and squirt technique' was introduced in 1881 by Hermann Vierordt, a doctor in Tübingen. He used shoes equipped with nozzles as a 'more direct way of setting down the complicated movements made during walking'.[18] Deliberately challenging the ideal type of result obtained by the Weber brothers, Vierordt understood his procedure primarily as a method for obtaining information about individual gaits and, beyond that, about pathological ones.

In addition, the contemporary gymnastics movement had published treatises to illustrate complex exercises on apparatus in visual form. The illustrations issued by Ernst W B Eiselen in *Abbildungen von Turn-Uebungen*, published in 1845 without any written commentary whatsoever, deserve special attention. The 417 lithographs show boys doing their exercises on apparatus, not only indicating the importance of the supporting hands but also using various lines to demonstrate the sequence of movements of the hands and legs during an exercise. In 1866 Justus Carl Lion had his *Turnübungen des gemischten Sprunges* published in Leipzig, illustrated with 294 woodcuts made from his own drawings.[19] Compared with Eiselen's illustrations, the simultaneous ones in Lion's book are particularly remarkable, combining several steps of an exercise in one image and thus providing a more complex idea of the sequence of the exercise (Figure 1).

Kohlrausch was well aware of the importance of explanatory illustrations, especially in the field of gymnastics, when he published

Figure 1 Straddle vault over a pommel horse, showing several phases of the movement sequence simultaneously.[20] *(Courtesy of Bayerische Staatsbibliothek, Munich)*

his *Physik des Turnens* in 1887 with 50 line drawings. This was a revised and enlarged edition of his article 'Mechanik des Turnens', published six years earlier. In the preface Kohlrausch noted that being in contact with Justus Carl Lion in Leipzig had provided the main impetus for the additional contents and that it was also Lion who had contributed the illustrations.[21] What stands out most in comparison with the older physical education textbooks is the predominance of the schematic representation of the laws of physics; only 17 illustrations show physical exercises. These include only as much of the gymnastic apparatus as is unavoidable for understanding an exercise. Greek letters joined by lines label the movements of the gymnast's centre of gravity during an exercise (Figure 2).

In the course of the five parts of this book focusing on 'the physical analysis of gymnastic exercises', Kohlrausch worked his way up to more and more complex patterns of movements.[23] It was only in the last third of his discussion that he gave apparatus gymnastics more weight than physics, explaining various exercises at the horizontal bar and mixed jumps with turns. Finally, in the appendix, Kohlrausch outlined the theoretical superstructure of his remarks in the context of the contemporary scientific discourse. The latter was based on the reductionist view of the human organism as an engine, which had developed in the mid-nineteenth century under the influence of progressive industrialisation and the leading research paradigm of thermodynamics.[24] In Germany this idea of 'organic physics' was shaped mainly by the physiologists Emil du Bois-Reymond, Hermann von Helmholtz, Carl Ludwig and Ernst Wilhelm Brücke, who had all been members of the Physikalische Gesellschaft since 1845. The conception of the body as a machine doing work was essentially a product of the discovery of the law of conservation of energy. Helmholtz had made an important contribution with his work *Über die Erhaltung der Kraft* in 1847. The other decisive influence on this

Figure 2 Shifting of the centre of gravity during swings on the horizontal bar, in four phases.[22] *(Courtesy of Bayerische Staatsbibliothek, Munich)*

conception of the body was the application of the concept of work from the machine to the human organism, an application Helmholtz had also advanced.[25]

In his *Physik*, Kohlrausch picked up elements of this conception of the body in order to apply them to exercises in the gym. Unlike in his earlier article, 'Mechanik des Turnens', the body in motion was now 'endowed with a power, as it were, which is called its vital force'[26] and accomplished a 'current task'. Kohlrausch was especially concerned with demonstrating the postulated law of the conservation of work in various apparatus exercises. In his presentation of the exercises, however, this axiom seems to have caused Kohlrausch some difficulty with the explanation model advanced. Only in the second part of the appendix, in which he replaces the 'vital force' with the concept of energy, did Kohlrausch introduce the 'mechanical heat equivalent' factor, known to science since 1842. This factor helped him to describe qualitatively the transformation of physical effort into other forms of energy, particularly heat.

Despite this conclusive interpretation of the body as a heat engine, Kohlrausch continued to fear that he could provide 'only something inadequate' with his physical explanation of the exercises. Unlike the physiologists' experiments, measurable proof for what he described was simply not possible because 'physicists have not yet performed experiments with equipment where the centre of gravity and moment of inertia could change at any time due to inner forces, or where the working forces are variable voluntarily, not only in direction and size but even in kind'.[27]

The chronophotography of human movement

In the meantime, however, chronophotography had made a recording medium available that opened up hitherto undreamed-of possibilities for visual documentation by providing a detailed record of movement. In 1872 Muybridge had begun to photograph the famous harness racers owned by Leland Stanford, the former governor of California and president of the Central Pacific Railroad. His pictures captured them in action on Stanford's farm in Palo Alto. In 1878/79, in order to record longer movement patterns, he developed a battery of consecutively operating cameras, first 12 and then 24. Connected with wires or strings that crossed the racecourse at right angles, their electric shutters were released by the horses themselves as they passed. The individual phases of the horses' movements were captured separately against a white background inscribed with numbers.[28] When one of these picture sequences appeared in *La Nature* in December 1878, Marey wrote to Muybridge at once. Later, when Muybridge projected his series photographs for an enthusiastic audience during his first trip to Europe in 1881, Marey welcomed him to an illustrious circle of scientists and artists, which also included Helmholtz.[29]

Gymnasts' circles had also taken note of these developments by this time. It must have been particularly distressing for Kohlrausch that two articles reporting on the importance of chronophotography for the field of gymnastics were published in the same year as his *Physik des Turnens*. Johannes Hermann of the Askanisches Gymnasium in Berlin referred to a series of pictures by Ottomar Anschütz in his article. He had to describe each of the pictures in turn because they could not be illustrated. According to Hermann, the didactic value of these photographs was due primarily to the fact that, unlike the plates in Eiselen's gymnastics book, they depicted the exercises 'not merely the way they are intended but actually carried out'.[30] Ferdinand August Schmidt, a doctor in Bonn, was concerned mainly with tracing the development of chronophotography from its precursors to the latest picture series by Anschütz. His remarks on the stroboscopic effect of flashes, the importance of the instantaneous shutter and the increasing sensitivity of photographic emulsions identified the technical conditions that from now on would allow photography to capture even rapid movements in accurately detailed snapshots.[31]

It is quite probable that Kohlrausch began to work on chronophotography and its applications for the study of gymnastic exercises right after the publication of his *Physik*. The first time he gave a paper on this body of work was at the 11th meeting of the Northwest German Gym Teacher Association in Celle in October 1889. There he referred mainly to the 'picture series by the photographer Anschütz which have also become very well known in gymnasts' circles'.[32] By creating an improved focal-plane shutter in front of the plate, Ottomar Anschütz had managed to shorten exposure times and thus obtain more precise detail when photographing moving subjects. In 1884 Anschütz worked with a battery of 12 cameras, which he had set up according to Muybridge's example. Two years later, with 24 improved cameras at the military riding institute in Hanover, he photographed over 100 series of riding exercises at all different paces.

With a view to the broadest possible application of chronophotography for 'private studies', Kohlrausch set about purposefully examining Anschütz's concept. Apart from the fact that the process seemed too expensive and complicated, he criticised the focal-plane shutter operating in front of the plate, which produced well-focused but 'less correct' pictures. Kohlrausch also doubted that the shutters in all 24 cameras worked uniformly. Finally, he considered the parallax caused by the different locations of the cameras a further disadvantage.[33] In deliberate contrast to Anschütz, Kohlrausch worked on an economical, transportable apparatus, arranging the 24 cameras on a wheel in order to avoid parallax.

Different solutions already existed for photographing a movement pattern from a stable optical axis. The oldest model with a rotating disc of negatives behind a stationary lens had been built by Pierre-César Jules Janssen in the form of his *revolver photographique* in 1874.[34] Marey introduced his *fusil photographique* eight years later, which, unlike Janssen's stationary device, could be used in motion and the moving subject kept constantly in sight. The shots, however, were as unable as ever to permit qualifying statements on movement in relation to space and time.[35] Therefore, Marey yet again built a stationary camera that same year, this time with a slotted disc rotating between the lens and a stationary plate. This made it possible to capture the movements of a person dressed in white against a black background with continuous multiple exposures in a partially superimposed, simultaneous image.[36]

Another principle of stationary chronophotographic equipment was developed by Albert Londe in 1882 at the Salpêtrière mental hospital in Paris. In his *appareil photo-électrique*, a slotted disc used as the shutter rotated between nine lenses inserted in a circle into the front of the camera and a stationary photographic plate; the frequency of the shots was electrically regulated by an adjustable metronome linked to a battery.[37] Ten years later, a second apparatus followed, with 12 cameras in three rows one on top of the other, and the individual shutters released by a separate electrical distributor.[38] Hippolyte Sebert completed an apparatus with a variant of this construction principle in Paris in 1890. It had six cameras, also arranged in a circle, and a separate shutter apparatus that released the six shutters behind the lenses one after another.[39] Finally, Louis-Aimé Augustin Le Prince, inspired by Muybridge's success, constructed a highly elaborate camera-projector in 1887. This used two strips of film behind 16 cameras in two rows, combined in a single body and fitted with electromagnetic shutters.[40]

Series photography of gymnastic exercises

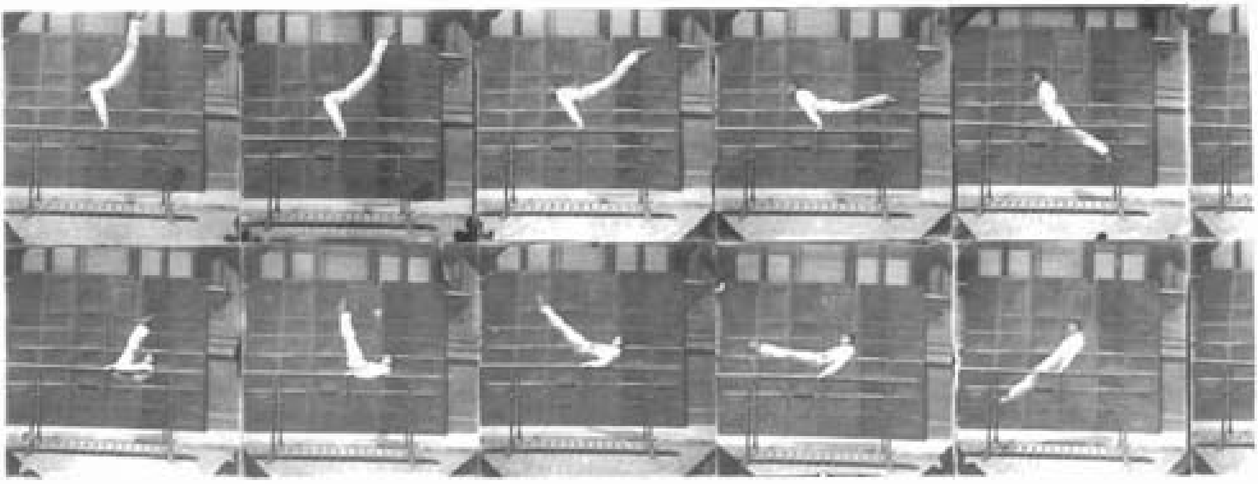
The extent of Kohlrausch's familiarity with these different designs is not known. At any rate, Joseph Maria Eder had described the principles of chronophotography as applied by Muybridge, Marey and Londe as early as in 1884.[41] Yet Kohlrausch never named anyone but Anschütz as an example for his experiments. Nevertheless, the apparatus he built refers to work by Janssen and Marey as well as Londe, rather than to the battery of cameras by Anschütz. His major innovation was that he not only made the light-sensitive photographic plate rotate but also combined it with a separate lens for each camera in a movable battery on a wheel. The circular movement of the 24 cameras, whereby each glides past the same shutter aperture in the encasing box, makes a shutter for each camera superfluous and avoids parallax at the same time (Figure 3).[42]

Equipment and image sequences were evidently already on display at the meeting in Celle in 1889.[43] Kohlrausch himself noted that he had 'built a new device for taking series photographs', which, 'in the kindly opinion of several expert gentlemen, were so successful that I thought I should give my consent to the publication of individual image sequences'.[44] Great store was apparently set by reproducing Kohlrausch's chronophotographs as authentically as possible in autotype, thus delaying publication of the lecture by two years. As Kohlrausch's inscription on the originals indicates, the image series he submitted for publication was not taken until July 1890 (Figure 4).[45] Kohlrausch had improved his photographic procedure considerably in the meantime, prompting him to have a later sequence printed. In fact, Kohlrausch seems to have used the printing delay to update his lecture as well. This becomes evident in the second part, where he went into detail about testing the equipment after completion in May 1890, that is, seven months after the lecture in Celle.

What pictures Kohlrausch actually showed at this lecture therefore remains an open question. At least they must have made quite an

Figure 3 Kohlrausch's first chronophotographic apparatus, 1890, seen from the back, with 24 negative mounts attached to a movable wheel operated by a hand crank. (Deutsches Museum)

impression; otherwise it would be hard to understand why he was granted 250 Reichsmark by the association to develop his ideas further.[46] Of the surviving original photographs by Kohlrausch, one possibility is a group of 24 undated snapshots, which, because most of them are underexposed and partly include double exposures, should be regarded merely as a test series.[47] These glass negatives, 40 × 40 mm

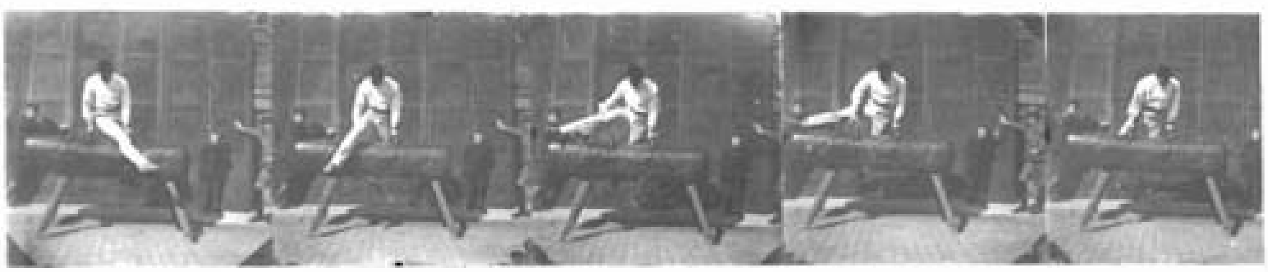


in size, give an idea of the usual setting that he was to use for quite a number of his later picture series. In order to take advantage of the daylight for his photography sessions, he had portable parallel bars set up in front of the school building and the gymnast dressed all in white to heighten the contrast.[48]

The illustration accompanying the published lecture shows a comparable setup for the exercise. Because of unfavourable weather conditions, Kohlrausch had only been able to take pictures on 15 July, the last day of school before the summer holidays. Other exercises were photographed in September and October. After that, Kohlrausch had to stop working temporarily because of the weak lenses and poor lighting conditions.[49] The 'Upstart from upper arm rest' was taken on this first day, during which Kohlrausch made various experiments and worked with different shutter widths in order to adapt them to the rhythm of the duration of the exercises and to the changing brightness of the sunlight.[50]

In September he photographed the 'Right leg circle on the side horse' in ten phases (Figure 5).[51] The figure on the right at the edge of the picture is closer to the centre in one of the pictures and almost disappears in another one. This shows that, contrary to what Kohlrausch claimed, the centre of the picture and the centre of the plate are not always identical.[52] Among the best sequences dating from

Figure 4 Ernst Kohlrausch, 'Upstart from upper arm rest', 15 July 1890, 22 phases, 40×40 mm. The (German) inscription says: 'High-school pupil Grote. Upstart from upper arm rest on the parallel bars. Taken on 15 July 1890, at about 12 o'clock. Intervals about 1/10 sec. Duration of exposure about 1/120 sec.' The original arrangement was similar to that in Figure 7. (Deutsches Museum)



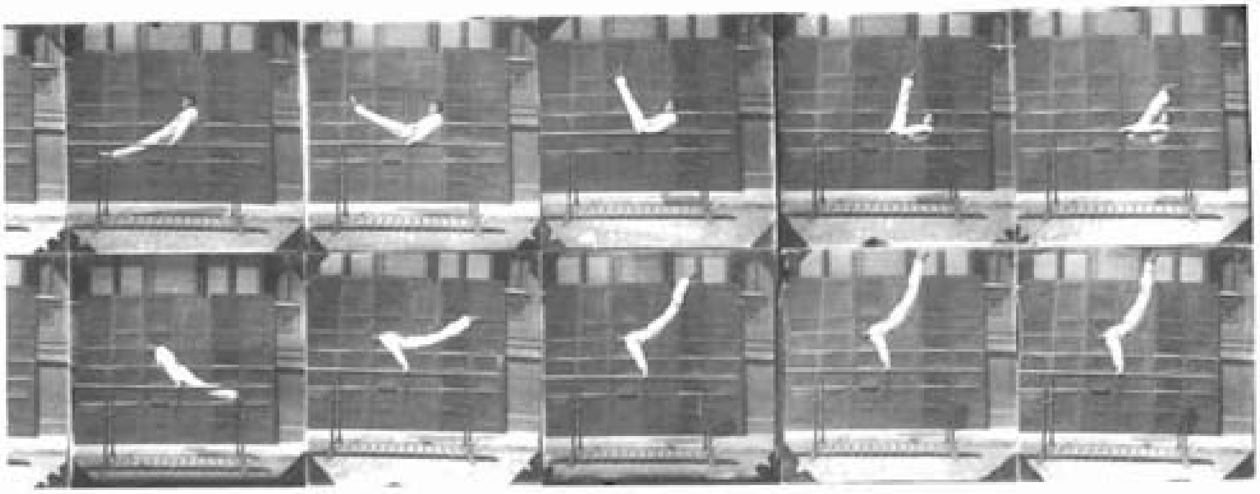
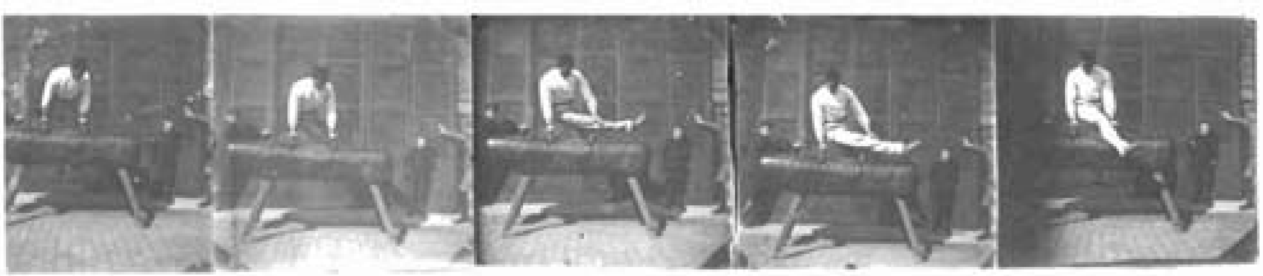


Figure 5 Ernst Kohlrausch, 'Right leg circle on the side horse', September 1890, ten phases, 40×40 mm. The (German) inscription says: 'High-school pupil Grote. Mid-September 1890. Noon. Intervals about 1/7 sec. Duration of exposure about 1/200 sec.' The original arrangement was similar to that in Figure 7. (Deutsches Museum)

this period are the series photographs of a buck vault, which was still used almost 40 years later to illustrate a handbook.[53]

Once he had applied for the patent for his photographic equipment (DRP 57133), Kohlrausch hesitated no longer before introducing the device to the photographic societies in Berlin. In November 1890 Hermann Wilhelm Vogel reported that Kohlrausch 'had built a series apparatus whose entire structure is completely new and original and so simple that it can be put on the market at a low price, eventually making the possibility of taking series photographs available to many people'.[54] In January 1891 Kohlrausch appeared in Berlin in person to present his 'series apparatus for instantaneous shots, along with many accompanying pictures'. He also reiterated the reservations against Anschütz's photographic system he had expressed earlier. This caused Anschütz to defend himself vehemently against these reproaches and, in turn, to criticise the 'unnatural foreshortening' due to the small lenses and the front lens shutter in Kohlrausch's equipment.[55]

Like Anschütz, whose projects had been funded repeatedly by the Prussian ministry of education, Kohlrausch applied to Minister Gustav von Goßler on 7 December 1890 for financial support totalling 4000 Reichsmark to make 'projected improvements' to his equipment.[56] After a high-ranking committee had reviewed his application and made suggestions for improvements, the grant was ultimately



approved.[57] Among the committee members identified by name were the physiologists Emil du Bois-Reymond[58] and Helmholtz and the physician Rudolf Virchow, as well as the industrialist Werner von Siemens, who provided assistance. This group had been familiar with chronophotography for some time: Helmholtz had met Muybridge in Paris as early as 1881; du Bois-Reymond and Virchow had written reviews on equipment by Anschütz;[59] and the Siemens & Halske firm was in the process of negotiating with Anschütz about the serial production of his *Schnellseher*.[60]

Although chronophotographs by Kohlrausch had been accessible to a broader public since 1891, no dated sequence of photographs from that year has survived. This suggests he was working out the design for his second camera by then (Figure 6).[61] He now abandoned the solid connection between lens and negative mount within one camera box. The cassettes for the 25 negatives were now attached to the outer edge of a light-proof encased wheel, while the four lenses moved independently on a disc at right angles to the wheel in front of it. The wheel and the disc of lenses were set in motion with a crank and synchronised by means of a gear mechanism, such that a lens always lined up superimposed on a negative. The diaphragm, inserted between the lenses and the picture wheel, contained two sliding bars to adjust the slit aperture. Kohlrausch was able to do without a separate shutter construction, as in his first apparatus. Only the beginning and end of the photographic series could be regulated by a mechanism counting the rotations. By combining a movable optical mechanism with an equally continuous movement of the negatives, Kohlrausch had based his design on the principle of optical compensation. This had been developed by Louis Ducos du Hauron back in 1864 and was picked up again by Charles Francis Jenkins 30 years later.[62]

Changing to a 9 × 12-cm rectangular picture format resulted in a decisive improvement in visual detail. The first sequences made with the new camera equipment, for instance the 'Original series photograph of a springboard jump' dated 11 October 1892, were taken in the familiar setting in front of the façade of the Kaiser Wilhelm Gymnasium.[63] The sequence of swings on parallel bars was probably also taken on the same day (Figure 7).[64] Comparing this sequence with pictures of the same exercise two years earlier clearly demonstrates the improvement in picture quality. In his *Physik des Turnens* Kohlrausch had commented: 'moving like a pendulum, which we do during swings from upper arm rest, e.g. on the parallel bars, might lead us to assume that the body is in balance during this exercise; yet this is not the case. In fact we have to re-balance the body constantly during these swings, which is difficult at first for weak gymnasts and causes many a beginner to fall [...]. During swings from upper arm rest, the steady fulcrums are not the shoulder joints but the hands'.[65] The sequence of photographs clearly demonstrates this

Figure 6 Kohlrausch's second chronophotographic apparatus, 1892, three-quarter view from the front, showing encased wheel with lenses perpendicular to the large wheel with 25 negative mounts operated by a hand crank. (Deutsches Museum)

observation by showing how the arms are slightly tilted to counter the shifting of the centre of gravity while the body swings forwards and backwards.[66]

Also dating from 1892 are two series of photographs possibly all taken on the same day at a swimming pool. The 23 phases of a not very well executed free hip circle backward on a horizontal bar set up in the water are the first large set of photographs taken with

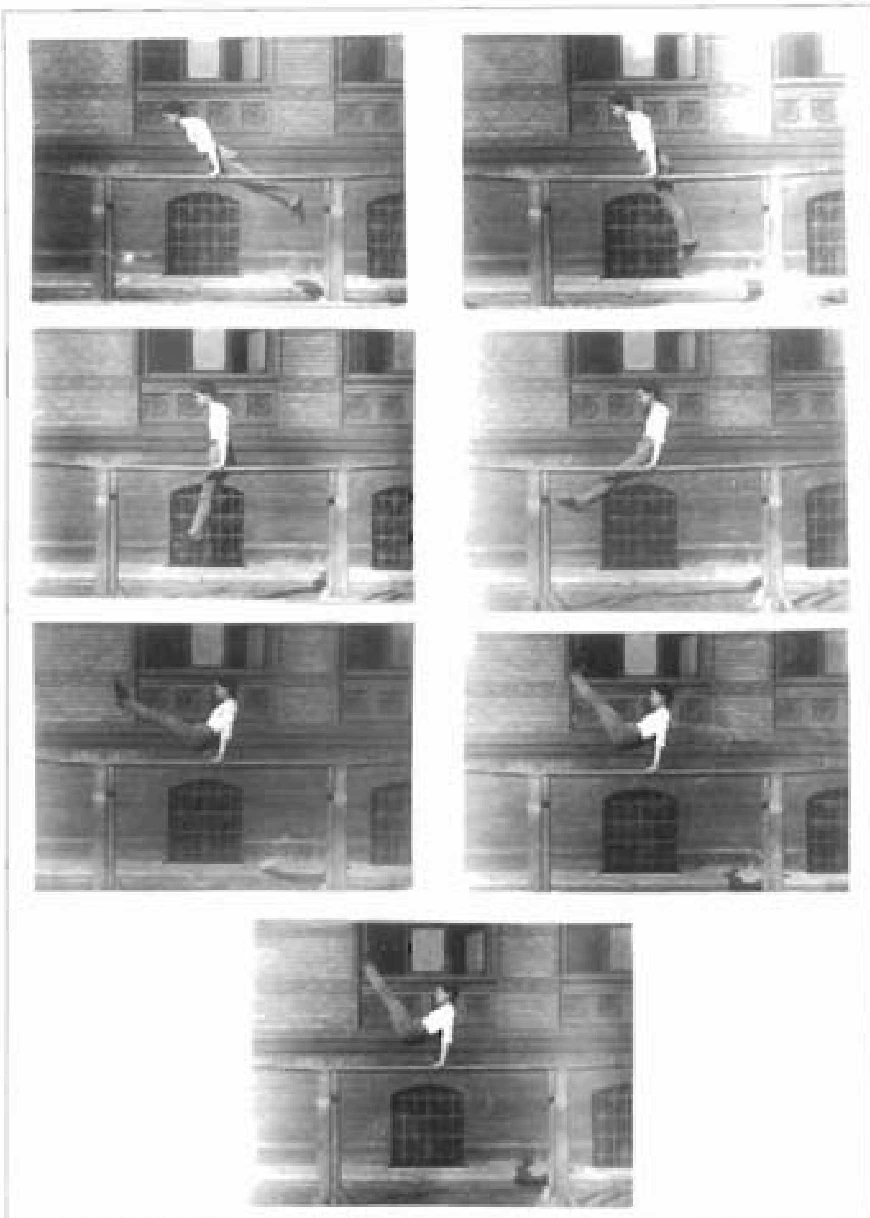


Figure 7 Ernst Kohlrausch, 'Swings on parallel bars', probably 11 October 1892, seven phases, 69 × 89 mm. (Deutsches Museum)

the second apparatus.[67] However, the insufficient exposure, lack of contrast and irregularities in the rhythm of the shots show that this sequence was far from meeting expectations. The fact that a backwards somersault in the water was also recorded on 12 lantern slides indicates that Kohlrausch was already working on projecting his image sequences at this point.[68]

On 6 July 1894 the second piece of photographic equipment was likewise subjected to testing at the Technische Hochschule in Berlin by a panel of unidentified experts headed by Vogel.[69] Two test series of a buck vault taken in bright sunlight were intended to demonstrate the way the camera equipment worked. Vogel's concluding appraisal reiterated his positive evaluation of Kohlrausch's device. However, as the surviving visual material testifies, Kohlrausch did not continue with the chronophotographic documentation of gymnastic exercises after that date.

Living pictures through projection

By isolating individual phases of movement, chronophotography had considerably expanded the possibilities for what pictures could capture. However, the deconstruction of rapid processes for the purposes of scientific study was only one application for this new photographic technique. For the first time, chronophotography had made available mechanically produced sequential pictures that promised a very high degree of reality when translated back into 'living' images. Therefore, a consequence that was practically imperative for the chronophotographers was to work on reproduction techniques that would show movement.

Kohlrausch had been dealing with this aspect from the start. To begin with, he turned his attention to popular kinetic viewing equipment such as the phenakistascope and the zoetrope. The use of equipment of this kind, which exploited the persistence of vision, had already been recommended for the first series photographs by Muybridge.[70] Kohlrausch too saw the potential 'of joining together the pictures that had been made by virtually dissecting the gymnastic exercise' in order to see 'the exercise itself recreated again'.[71]

Viewing equipment with pictures on paper was necessarily limited to private use. Projection, on the other hand, could reach a larger audience, making public showings and hence commercial exploitation feasible. As early as 1843, T W Naylor had proposed combining the phenakistascope with a projection lantern, a combination further developed by Franz von Uchatius and Louis Jules Duboscq. Emile Reynaud also expanded his praxinoscope into a projector in 1882. While all of these devices used painted images, Henry R Heyl equipped his phasmatrope of 1870 with photographs, showing people in different positions.[72] Muybridge's zoopraxiscope of 1879 was the first to use series photographs for projection, but these plates were not real transparencies either, as they only showed painted silhouettes copying the photographs.[73] Only Anschütz succeeded in projecting his own chronophotographs in life size with his projecting electrotachyscope in 1894.[74]

Appearing in parallel were several reproduction devices now working with original photographs, but they only allowed pictures to be looked at on a small milk-glass viewing screen. The first example of this peepshow principle was presented by Anschütz in 1887 with his electrotachyscope, conceived along the lines of the phenakistascope scheme, which was the first to contain lantern slides of series photographs. Series production of his improved *Schnellseher*, by Siemens & Halske in Berlin-Charlottenburg, began in 1891, thus marking the beginning of the industrial marketing of 'living' images. Using this construction principle, a variant by the name of phonoscope was created by Demeny in 1892.[75] In Ludwig Stollwerck, the ingenious sales manager of the Cologne chocolate company, Demeny had also found a partner who was interested in the commercial exploitation of his inventions.[76] And, just as with Anschütz, expectations for profitable marketing were not met and the business connection was dropped again in 1895. The trend-setting kinetoscope by Thomas Alva Edison already worked with 35-mm-wide perforated film rolls, which passed continuously via a system of spools behind an eyepiece on top of the box. While Anschütz's and Demeny's picture sequences 'flew by' in less than 1 second, Edison's 'movies' consisting of 900 separate pictures lasted almost half a minute.[77]

Exactly when Kohlrausch started to develop a projector cannot be determined with certainty. He had at any rate had the opportunity of seeing the zoopraxiscope in action because Muybridge had shown 'almost life-sized pictures of locomotion' at the Urania in Berlin on 21 March 1891.[78] Both of Kohlrausch's projectors were designed for an image size of 8 cm^2. This means the projectors are not associated with the small photographic format of his first piece of camera equipment, as copying and enlarging the photographs afterwards would have been unlikely. However, the series photographs of a backward somersault of 1892, a tableau of 12 glass lantern slides in the larger 8-cm^2 format, suggest that Kohlrausch was not only working on his second photographic device but also building his first piece of projecting equipment at this time.[79] This equipment was never mentioned by Kohlrausch and its existence was unknown until 1933, when his estate was bequeathed to the Deutsches Museum (Figure 8).[80] The circular arrangement of 21 pictures on a disc follows the construction principle of the zoopraxiscope. Deviating from it, however, is a smaller disc instead of a fixed lens in front of the picture disc. Coupled to the picture disc by a gear mechanism, it has three openings, into which three lenses could be screwed. The blackouts that come about through the rotation of both elements are essential for flicker-free reproduction and make a shutter unnecessary. This construction principle, with a moving disc of lenses that rotates seven times for each rotation of the picture disc, is directly related to Kohlrausch's second photographic apparatus and its similarly rotating disc of lenses. The device quite obviously did not meet expectations, which also explains why it was suppressed by its inventor.

In the second projector, 20 picture gates on a fixed ring are coordinated with the same number of lenses on another similarly fixed ring in front of them (Figure 9).[81] As the picture wheel is not

Figure 8 Kohlrausch's first projecting apparatus, 1892/93, three-quarter view from the back, showing the hand crank, the disc for 21 lantern slides and the disc for the lenses behind it. (Deutsches Museum)

moved, an independent solution had to be found for allowing in light. The movable device for directing light, which Kohlrausch invented for this projector, had already been realised in 1847 by Ludwig Döbler in his phantascope.[82] Although there is no indication that Kohlrausch knew of this type of construction, his second projector seems like a modernised adaptation of this older device. Kohlrausch had attached

Figure 9 Kohlrausch's second projecting apparatus, 1895, front view, showing 20 lantern slides on a fixed ring and a movable 'arm' behind it for introducing light. (Deutsches Museum)

an 'arm' that could be rotated around the central axis in front of the ring with the picture gates. Via two condensers and two deflecting mirrors, this arm reflected the light entering at the level of the axis onto the picture gates. While it rotated, this movable element lit up all the slides on the picture wheel. Mounting the lenses on radial metal carriages ensured that the individual lantern slides, depending on their respective distances to the screen, could be brought into line in a common image field.

Kohlrausch first presented this second piece of projecting equipment in 1897 at the meeting of the Gesellschaft deutscher Naturforscher und Ärzte in Brunswick.[83] Kohlrausch had another opportunity to show his projector the following year at the 16th Congress of Internal Medicine in Wiesbaden. As for the construction of projection equipment, the authority Kohlrausch cited was Eduard

Hitzig, who had set up a mental hospital in Halle in 1885. It was on his initiative that Kohlrausch had taken the picture series presented at the congress, showing them in the usual 'stroboscopic drums' for the time being. Hitzig had encouraged Kohlrausch, saying 'that they would furnish eminently useful demonstration material, especially if the series could be turned to account by projection'.[84]

From physiology to pathology

With the pictures he showed in Brunswick and Wiesbaden, Kohlrausch had departed from his original area of interest. The testing of his second photographic device in 1894 and the image sequence of a buck vault made on this occasion can be seen as signifying a halfway mark, questioning the exclusive concentration on the chronophotography of gymnasts. Only one year later, however, a completely new field of activity presented itself. In 1895 he made several image sequences of the gaits of the mentally ill, first in Bad Oeynhausen and later in Hanover.[85] Kohlrausch was able to exhibit some of these a year later at the International Amateur Photography Exhibition in Berlin and was awarded, along with Anschütz, a medal of honour.[86]

Muybridge, Marey and Londe had also worked on studies of pathological motion, thereby making chronophotography available to medical diagnostics.[87] In the first issue of the *Internationale Medizinisch-Photographische Monatsschrift* in 1894, Londe wrote about the utility of chronophotography in the service of medicine. This article probably inspired Kohlrausch's work in this field.[88] Five of Kohlrausch's image sequences studying pathological gaits have been preserved. The 'Tabes dorsalis' series (Figure 10), comprising 24 phases taken on 24 July 1895 in Bad Oeynhausen, can without a doubt be regarded as the most successful.[89] A new element added to the scene is the chronometer on the wall. This suggests for the first time that the purely descriptive reproduction of movement that Kohlrausch had made until then was no longer considered adequate to meet the needs of the medical specialists. Marey had begun some time earlier to record his movement sequences in their temporal course with a chronograph integrated into the picture.[90] In addition, graphic marks on the front side of the podium provided information on the spatial dimension of the movement.[91] In contrast, Muybridge's pictures for the University of Pennsylvania from 1884 onwards had worked with grid-like structures on the black background of the pictures. However, as each phase was taken with a different camera and the time intervals between the individual photographs and the exposure times were by no means always the same, this procedure could not satisfy the requirements for an analysis of the space–time relationship.[92]

Four other sequences of shots by Kohlrausch were obviously made in different surroundings.[93] Kohlrausch presented two series in Brunswick in 1897, yet quite clearly failed in his attempt to convince

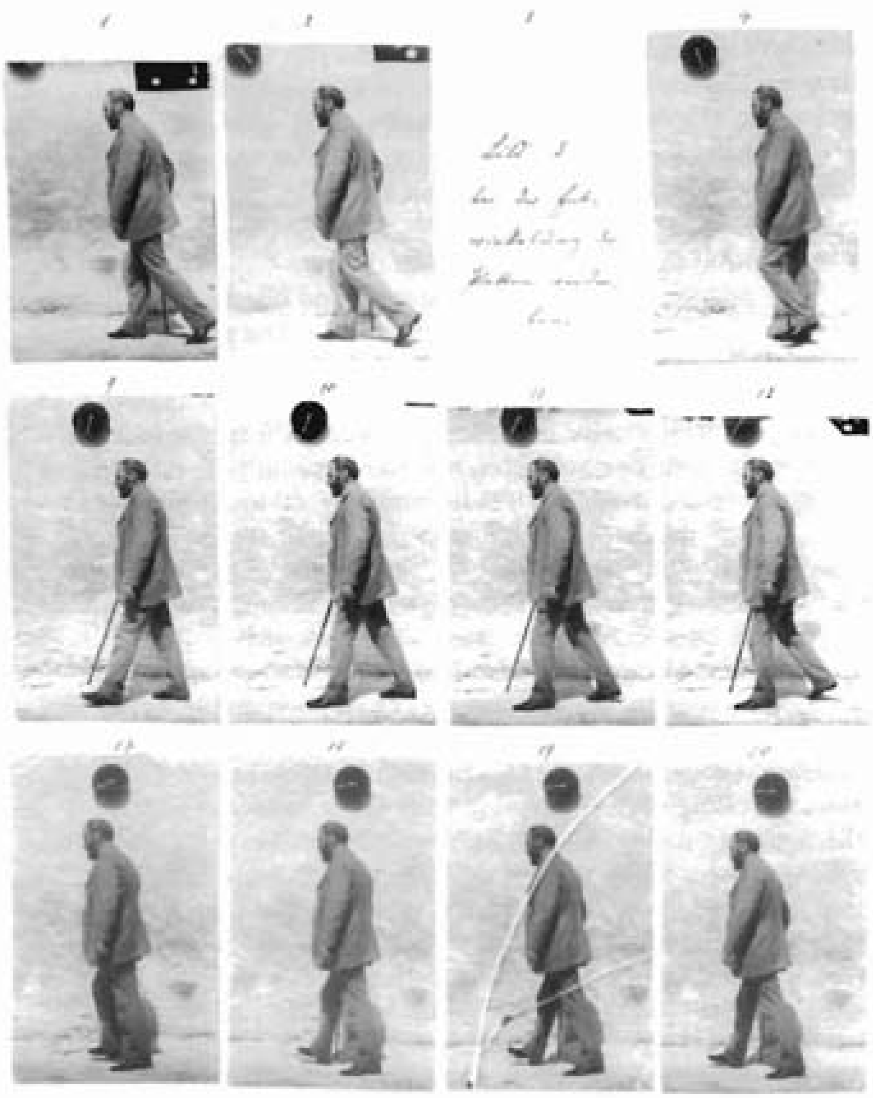


Figure 10 Ernst Kohlrausch, 'Tabes dorsalis', 24 July 1895, 11 of 24 phases, 70×42 mm. The German inscription says: 'The hand of the clock makes one complete revolution in 3⅓ sec. The thin lines around the edge of the dial are very clear on the plates (with a few exceptions), but are lost during the printing process due to halation. The sunlight was bright. The plates are developed to 13 and 12 (the latter less dense). The plates of each group equally strong. Kohlrausch.' (Deutsches Museum)

medical specialists of the usefulness of his technique. Sufficient grounds for rejection were provided soon after, when René du Bois-Reymond, a physiologist like his father, spoke on 'scientific series pictures' in the service of kinetics.[94] As he was concerned mainly with obtaining measurable data, the only pictures that seemed to fulfil these requirements were the simultaneous ones, most recently further developed by Wilhelm Braune and Otto Fischer on the basis of Marey's 'photographie partielle'. Moreover, since 1895 cinematography and X-ray photography had been opening up completely new possibilities for ways of looking at the human body. Both procedures were represented at the conference in Brunswick by speakers who used both words and images to explain the utility of these new techniques for medicine. In addition, a separate lecture was devoted to the representation and analysis of pathological motion with the aid of a cinematograph.[95]

In view of these overwhelming arguments, Kohlrausch deliberately picked up the comparison with film a year later in Wiesbaden. He knew how to interpret the apparent shortcomings of the brief intervals to his advantage: as he was only dealing with periodic movement processes of brief duration anyway, they could be shown larger and more clearly than with a cinematograph. Moreover, according to him, both the 'completely regular rhythm' of the photography and the 'completely still position' in which the photographs were reproduced were special advantages distinguishing his technique from the more recent film process. Nor, this time, did Kohlrausch neglect to outline for his audience his device's possible applications to clinical medical education. Being equipped with sequential photographs of rare syndromes would mean having study material for teaching clinical medicine available at all times. This would mean producing more image sequences and, above all, more projectors. At an estimated price of 300 Reichsmark for the projector and 15 Reichsmark for the individual series of images, Kohlrausch was able to specify the scale of costs for the proposed investment.[96] Despite these efforts, the medical press did not pay any special attention to Kohlrausch's contribution to pathology.[97]

The preoccupation with chronophotography had already passed its zenith by this time: Muybridge had not shot any more new series since 1885, and now devoted himself exclusively to his publications and lecture tours.[98] Londe set up the first X-ray laboratory in a Parisian hospital at the Salpêtrière in 1896/97.[99] Demeny, after the intermezzo of the unsuccessful commercialisation of his chronophotographic equipment, went back to his first passion, physical education.[100] Anschütz, too, gave up working on chronophotography entirely in 1895 after his presentations in Berlin.[101] Only Marey, thanks to government support, was able to continue, managing to delimit his work from the rapidly rising film industry and the commercial use of film, until his death in 1904.[102]

Kohlrausch probably ended his photographic activities as early as in 1895 with his image sequences for pathology. He then turned to making improvements to his projecting equipment. However, any hopes for the further use and possible commercial exploitation of his chronophotographic devices had been dashed ever since the doctors' convention in Wiesbaden. Like Demeny, Kohlrausch therefore went back to the competitive team sports that had occupied him before he set out towards his *Physik des Turnens* and the adventure with chronophotography.[103] He was probably only working casually on a cinematographic apparatus before the First World War. It combined a large number of mobile recording and projecting lenses with what was by now a strip of film, but it never got past the design stage.[104]

Kohlrausch received one last substantial tribute in the context of chronophotography in 1898 from Ludwig David, an Austrian artillery lieutenant, who had made ballistic snapshots. He paid special tribute to Kohlrausch's second photographic device, despite the fact that it had been available 'only as a test model for the time being'.[105] As it never left this test model stage, Kohlrausch's work was soon forgotten by the field of film research. The specialist literature of the gymnastics movement, however, continued to keep alive the memory of his contribution to the analytical research of the sequence of movement until the 1920s.[106] F A Schmidt, a doctor who was a friend of Kohlrausch and had followed his chronophotographic activities attentively, sincerely regretted that 'this beautiful start ultimately ended in failure'.[107] Schmidt was consequently all the more willing to use the opportunity to illustrate the 'Bewegungslehre der Leibesübungen' in his handbook with a large number of chronophotographs by Kohlrausch, among others.[108] In the *Handbuch des gesamten Turnwesens* by Rudolf Gasch, published in 1920, the subjects of 'the physics of gymnastics' and 'photography and gymnastics' were each covered in chapters of their own. Although the cinematograph had by then prevailed for 'obtaining picture sequences for the study of gymnastic movements',[109] Kohlrausch was given prominence once more, as opposed to Muybridge, Anschütz and Marey, for the particular suitability of his technique for recording locomotion.

With his series photographs based on a fixed optical point of view, Kohlrausch had made an independent contribution to chronophotography that had grown out of his research into the workings of gymnastic activity. In trying to capture the transient movements of the gymnasts in separate steps, Kohlrausch had developed a complex moving mechanism in his photographic equipment that was unique in this form. Lacking a photographer's training and being tied up in the strict routine of giving school lessons, Kohlrausch had been largely on his own when carrying out his projects. In the context of the international development of concepts pertaining to this visual recording system on the eve of the motion picture, his home-made effort also acquires a certain tragic touch. In retrospect, the material presented here nevertheless develops a certain logic that was lost on the contemporaries involved, in which success and failure seem inseparably interwoven.

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